(12) UK Patent Application (19) GB (11) 2 184 323 (13) A

(43) Application published 17 Jun 1987

(21) Application No 8530595

(22) Date of filing 12 Dec 1985

(71) Applicants
Midlen Trading Corporation

(Incorporated in Bahamas)

50 Shirley Street, P.O. Box N-10496, Nassau, Bahamas

(72) Inventor
Frank Villa

(74) Agent and/or Address for Service
J. Y. & G. W. Johnson, Furnival House, 14-18 High Holborn, London WC1V 6DE

(51) INT CL[4]
H04R 1/20

(52) Domestic classification (Edition I)
H4J 30F 33A BA

(56) Documents cited
US 4361736

(58) Field of search
H4J
Selected US specifications from IPC sub-class H04R

(54) **Loudspeaker system**

(57) A loudspeaker with omnidirectional radiation properties has a vertical enclosure (1) extending from a support, an electro-acoustic transducer having a diaphragm (2) closing an opening in one end of the enclosure distal from the support and a baffle (3) mounted beyond said one end opposite an outer surface of the diaphragm so as to define a continuous peripheral opening between the baffle and the enclosure which is less than one quarter of the shortest wavelength to be radiated. Preferably the baffle is profiled so that the distance between the diaphragm and the baffle is nowhere greater than one quarter of the shortest wavelength to be radiated, thus suppressing unwanted resonances in the opening. A second baffle can be mounted opposite a bass reflex opening (26) in the other end of the enclosure so as to define a second continuous peripheral opening. The transducer may be a low range unit, with a third baffle (15) mounted beyond baffle (3) to provide a third peripheral opening (24) from high range transducers (16) mounted opposite each other on the first (3) and third (15) baffles.

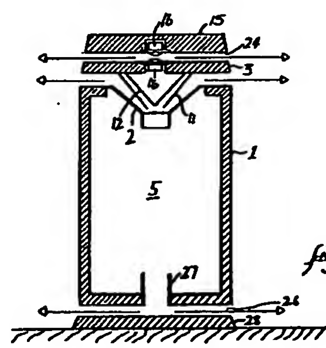

fig 8

GB 2 184 323 A

2184323

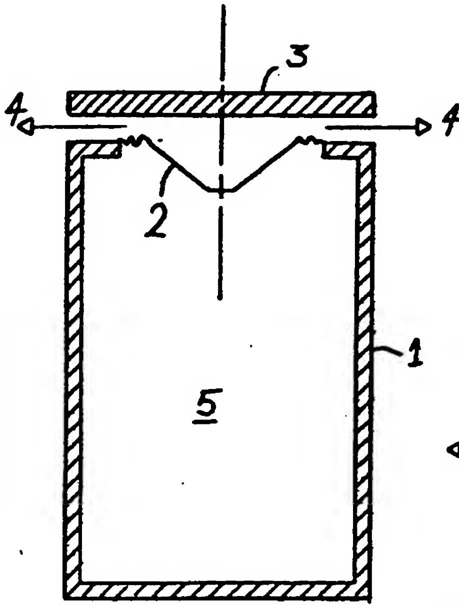

fig. 1

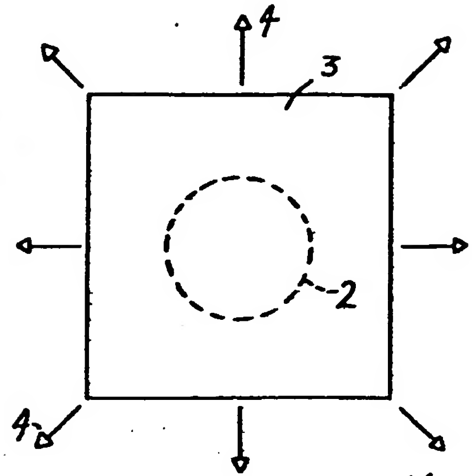

fig. 2

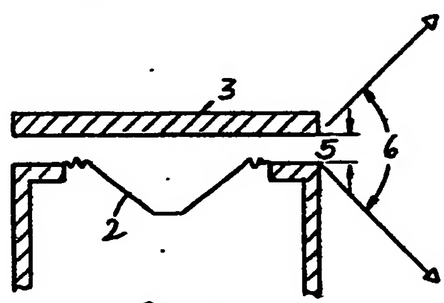

fig. 3

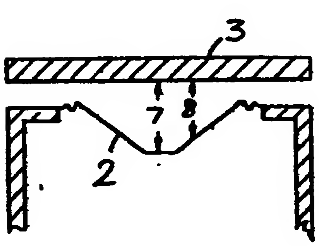

fig. 4

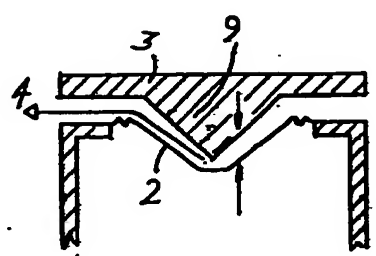

fig. 5

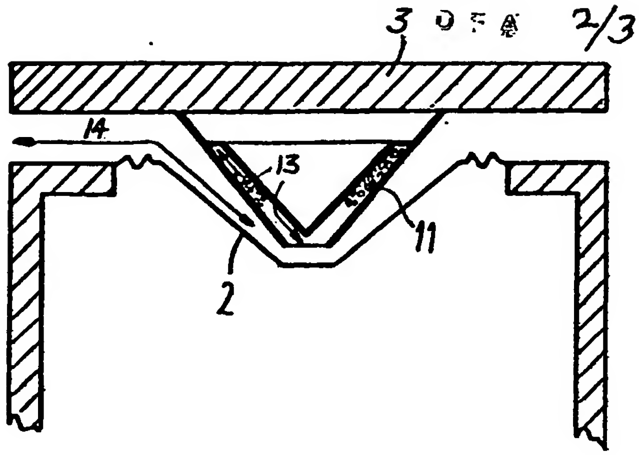

fig. 6

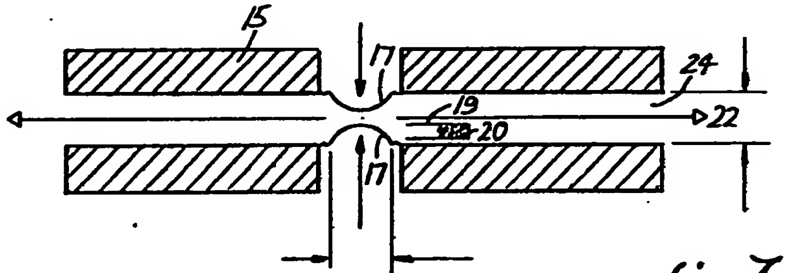

fig. 7

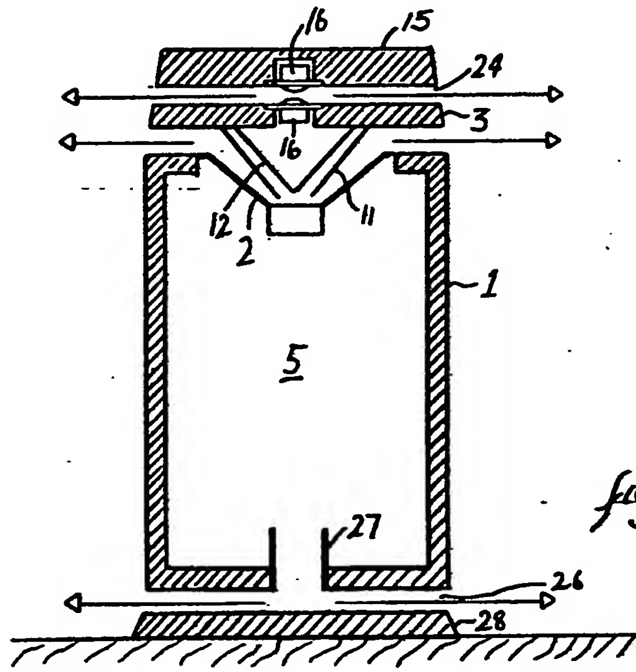

fig. 8

2184323

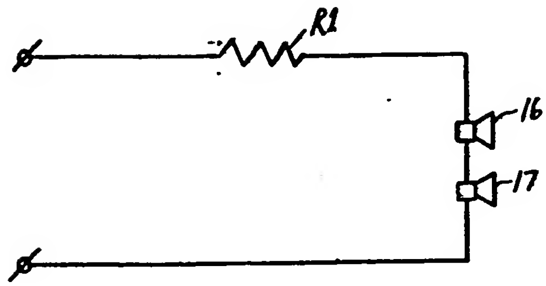

fig 9

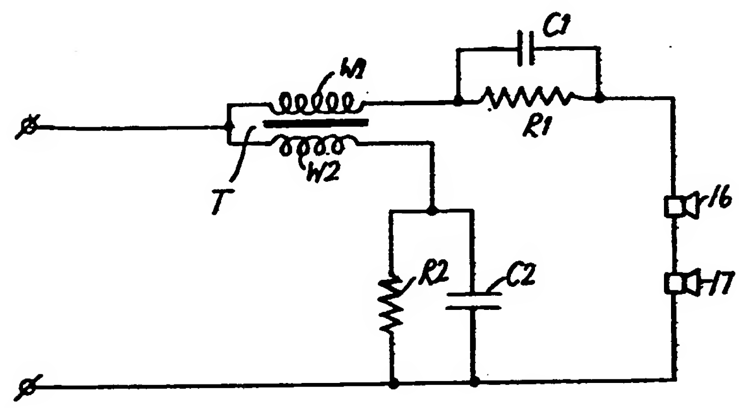

fig 10

SPECIFICATION

Loudspeaker system

This invention relates to loudspeaker systems comprising drivers in the form of electro acoustic transducers within an enclosure.

The function of a loudspeaker enclosure, apart from aesthetic considerations and the necessity to protect the drivers, is to couple the drivers acoustically to the surrounding environment, typically by providing acoustic separation between the two sides of a transducer diaphragm, and supplying a suitable air cavity to one side of that diaphragm such as to provide acceptable electro-acousric efficiency in the lower portions of the audible frequency spectrum. The vibratory motion of the transducer diaphragm has the effect of generating pressure waves in the elastic medium surrounding it, i.e. the ambient air, and the effect of the enclosure is usually to confine this generating action essentially to the exposed or outer surface of the diaphragm. This necessarily imparts directional characteristics to the system.

The intensity of the pressure waves emitted by the diaphragm is always highest on the central axis of the diaphragm, and the polar response of such a transducer falls off with increasing angular displacement from the central axis. It is well known and can be demonstrated mathematically that this fall off occurs more rapidly as the frequency radiated increases, and as a broad generalization, the larger the diaphragm, the more concentrated its emission at any particular frequency will be towards the central axis. Since the dimensions of the diaphragm are fixed, the angle over which radiation intensity is reasonably well maintained varies in inverse proportion to the radiation frequency.

Within the conventionally accepted limits of the audio frequency spectrum, namely 20 Hz and 20KHz, the wave length of sound in air varies between 16.5 metres and 1.65 centimetres. This entails that any transducer with a diaphragm of practical size will have a polar response ranging from practically spherical at the lower end of this range to narrowly directional at the upper end of the range. Since it is normal practice in practical loudspeaker system to divide the range and assign it to two or more transducers, having typical diameters of 20 to 30 centimetres for the lower end of the range and 2.5 centimetres for the high end of the range, the effective radiation angle of a modern commercial system typically varies from 360° at 20 Hz to about 60° at 20KHz. Effective stereophonic perception with standard 2 channel commercial systems requires a sufficiently wide radiation pattern across the whole audible range for effective generation of a stereophonic image, and it is usually pleaded that the radiation angles provided by conventional systems are sufficient for acceptable performance. However, the limited radiation angle at certain frequencies in fact requires that the listener be rather precisely located relative to the two systems, and that the acoustic environment is suitable, both of which requirements are difficult to meet in practic in domestic situations.

Published research has suggested that the non-uniform polar response of loudspeakers in conjunction with uncontrolled acoustic characteristics of the listening environment are a major source of deficiencies in the tonal and image response of stereophonic systems.

It is believed that these problems are substantially alleviated if a loudspeaker system is provided with an essentially uniform omnidirectional radiation pattern. Whilst a number of units have been marketed having allegedly omnidirectional radiation patterns, these either utilize arrays of transducers aimed in different angular directions, or use reflective paddles to scatter the emission of a single transducer. By and large the polar response of such units has been by no means spherical, and has remained frequency dependent, and/or the appearance of the units has been less than satisfactory.

It is an object of the present invention to provide a loudspeaker system which can provide a good approximation of a spherical radiation pattern, and also facilitate production of a unit having a satisfactory appearance.

Accordingly the present invention provides a loudspeaker system comprising an enclosure extending vertically into a room from a support, an electro-acoustic transducer having a diaphragm closing an opening in one end of the enclosure distal from the support and a baffle mounted beyond said one end opposite an outer surface of the diaphragm so as to define a continuous peripheral opening between the baffle and the enclosure which is less than one quarter of the shortest wavelength to be radiated. Preferably the baffle is profiled so that the distance between the diaphragm and the baffle is nowhere greater than one quarter of the shortest wavelength to be radiated, thus suppressing unwanted resonances transversely of the slot.

Preferably also a second baffle is mounted opposite a bass reflex opening in the other end of the enclosure so as to define a second continuous peripheral opening between the enclosure and the second baffle, and preferably also the first electro-acoustic transducer is excited only by frequencies in a lower part of the audio frequency spectrum and a third baffle is mounted beyond the first baffle so as to define a third continuous peripheral opening extending from further electro-acoustic transducers mounted facing each other on the first and third baffles.

Preferably means are provided within the openings between the enclosure and the first baffle, and between the first and third baffles so as to trap unwanted resonances occasioned by the radial increase in cross section of openings with respect to the axes of the transducers failing to comply with an exponential law.

Further features of the invention will become apparent from the following description with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic cross section through a loudspeaker system, illustrating certain basic features of the invention;

Figure 2 is a plan view of the system shown in Figure 1;

Figure 3 and 4 are fragmentary views corresponding to Figure 1 and illustrating certain characteristics of

the system;

Figure 5 is a further fragmentary vertical section of a modified embodiment illustrating a further feature of the invention;

Figure 6 is a corresponding view showing a further developed embodiment;

Figure 7 is a vertical cross section illustrating an assembly utilized for the reproduction of high frequencies;

Figure 8 is a vertical cross section through a preferred embodiment of the invention;

Figure 9 illustrates a basic arrangement which may be used to drive the high frequency electro-acoustic transducers shown in Figures 7 and 8; and

Figure 10 illustrates the equalizing network utilized to drive these transducers.

Referring to Figure 1, a vertically extending enclosure 1 stands on or is supported from the floor of a room in which the unit is to be used. It will normally be most convenient for the unit to be floor standing, but it should be understood that any other arrangement allowing omnidirectional radiation at an appropriate level would be possible. For example, the unit could be inverted and suspended from a ceiling. Mounted in an opening in the top of the enclosure is an electro-acoustic driver unit or transducer having a diaphragm 2. Spaced from the top of the enclosure is a baffle 3 which cooperates with the enclosure to define a continuous peripheral opening for the emission of sound waves 4 as seen in Figures 1 and 2.

Referring to Figure 3, the width of the opening 5 is selected to be less than a quarter of the wave length of the highest frequency to be handled by the driver, with the result that, over the entire frequency range to be handled, the sound will radiate from the opening over a wide angle 6. Obviously there will be reduced radiation in a vertically upward or downward direction, but in practical listening situations this will not constitute a significant deviation from a spherical radiation pattern.

A problem with the arrangement shown in Figures 1 to 3 is that with a conventional conical diaphragm 2 there will be varying distances 7 and 8 between different portions of the cone 2 and the baffle 3, which are likely at certain frequencies to be sufficient to constitute a quarter wave length or an integral number of quarter wave lengths of a frequency being handled, thus setting up unwanted resonances in the opening between the enclosure and the baffle. In order to overcome this problem, the baffle may be configured as shown in Figure 5, by providing a conical downwardly directed plug 9 which projects into the cone of the diaphragm so as to maintain the distance 10 between the plug and the diaphragm less than one quarter of the wave length of the highest frequency to be handled.

Although this arrangement avoids the generation of unwanted resonances due to the spacing of the diaphragm and the baffle, unwanted and deliterious variations in the acoustic impedance of the opening at different frequencies will still arise since the rate of radial increase in the cross section of the opening, referred to the central axis of the diaphragm, will still depart considerably from the exponential low desirable for a smooth response.

In order to overcome this problem, the arrangement shown in Figure 6 may be employed. The hollow plug 9 of Figure 5 is changed to a hollow frustum 11 of a cone surrounding a solid inner cone 12 so as to form a quarter wave trap 13 dimmensioned so as to absorb the unwanted resonances. The Q or figure of merit of the trap may be adjusted by introducing damping material within the cavity 13.

Figure 7 illustrates how omnidirectional radiation may be achieved from conventional middle and high frequency or high frequency driver units. Two horizontal baffles 15 are located opposite one another, each baffle supporting a driver unit 16 (see Figure 8) having a domed diaphragm 17. The diaphragm 17 are arranged co-axially facing each other in close proximity, and are driven so that the diaphragms move in phase opposition. This opposite motion 21 has the effect of generating radial pressure waves 22, whilst the radial length of the opening 24 is large compared with the wave length of the sound being radiated except at the bottom of the frequency range. The residual anomaly at that point may be corrected by the provision of a quarter wave trap 19 consisting of a pipe closed at one end and tuned to the appropriate frequency, its acoustic properties being adjusted using a quantity of damping material 20. The asymmetric placement of the trap as shown in Figure 7 is immaterial, since the offset is short compared with the operating wave length.

Figure 8 shows a complete enclosure incorporating the features already described above. In this instance, the interior 5 of the enclosure 1 is provided with a bottom vent 27 in order to form a base reflex enclosure, the vent 27 communicating with the ambient air through a further opening 26 formed by spacing the enclosure 1 from a further baffle 28. The entire assembly is held together by a number, typically 4, of threaded rods (not shown) which tension the top baffle 15 to the base baffle 28, using suitable spacers for maintaining the proper openings between the various baffles and the enclosure.

As mentioned above, the transducers 16 should be driven so that their diaphragms move in phase opposition. Since the diaphragms are physically opposed, both transducers should be driven by the same electrical signal. and thiiiss is achieved by placing them in series. Since the operation of the transducers 16 in close proximity results in a three dB increase in efficiency over that of a single unit, the series connection may be utilized whilst still maintaining the same efficiency. Resistor R1 is connected in series to bring the overall efficiency down to the level of that of the low frequency unit. To quote à specific example, transducers 16 might be 6 Ohm units rated at 92 dB efficiency. The series connection results in 92 dB efficiency with a resulting impedance of 12 Ohm. If the efficiency of the low frequency unit is 87 dB, resistor R1 may be 10 Ohm, the impedance of the system shown in Figure 9 thus being 22 Ohm.

One matter which requires to be taken into consideration in the design of a truly omnidirectional unit is that transducer are normally designed to provide a flat frequency response on their central axis. Since the radiation pattern becomes more concentrated along the axis as the frequency increases, the actual overall

power output of the transducer must decrease with frequency. If the polar response is rendered substantially spherical as in the present invention, and conventional transducers are utilized, the power output in any particular direction will fall with frequency since the radiation at the higher frequencies is less concentrated. Typically, this fall off in power output as compared to the axial response of a conventional unit may amount to about 15 dB at 20 KHz relative to the mid range response. One way of resolving this problem is illustrated in Figure 10, where a differential transformer T with windings W1 and W2 running in opposite directions and presenting a ratio of 2:1 is provided, with the winding W1 in series with a circuit similar to that shown in Figure 9, and the winding W2, together with a compensation network is connected in parallel thereto. Assuming the effect of capacitors C1 and C2 to be negligible at middle frequencies, then if the current in winding W2 is twice that in winding W1, the net magnetization of the transformer core is zero; thus the windings W1 and W2 present no inductance and provide no transformer action. In a specific example, if the combined impedance of R1, and transducers 16 and 17 is 22 Ohm, then the value of resistor R2 should be 11 Ohm. As the frequency increases, the impedances of the capacitors C1 and C2 fall to levels which are low compared with those of the resistors R1 and R2, such that at the top of the audio frequency range, transformer action between the windings will cause the voltage at the output of winding W1 to be three times that at the input end, providing a top end boost of 9.5 dB. At the same time, the effect of R1 is reduced, providing a further 2.5 dB boost. By this means, compensation can be provided for the omnidirectional distribution of the high frequency radiation, whilst maintaining the impedance of the network as a whole at a satisfactory level, typically 4 Ohm at 20 KHz.

Since the system described has an essentially box shape, and the only openings required are the three peripheral slots which will normally be parallel and horizontal, the appearance of the system can readily be made acceptable. The system need not of course have a rectangular plan as shown in Figure 2 and both round and other polygonal forms would be possible.

CLAIMS:

1. A loudspeaker system comprising an enclosure extending vertically into a room from a support, an electro-acoustic transducer having a diaphragm closing an opening in one end of the enclosure distal from the support and a baffle mounted beyond said one end opposite an outer surface of the diaphragm so as to define a continuous peripheral opening between the baffle and the enclosure which is less than one quarter of the shortest wavelength to be radiated.

2. A loudspeaker system according to Claim 1, wherein the baffle is profiled so that the distance between the diaphragm and the baffle is nowhere greater than one quarter of the shortest wavelength to be radiated.

3. A loudspeaker system according to Claim 1 or 2, wherein a second baffle is mounted opposite a bass reflex opening in the other end of the enclosure so as to define a second continuous peripheral opening between the enclosure and the second baffle.

4. A loudspeaker system according to Claim 1, 2 or 3, wherein the first electro-acoustic transducer is excited only by frequencies in a lower part of the audio frequency spectrum and a third baffle is mounted beyond the first baffle so as to define a third continuous peripheral opening extending from further electro-acoustic transducers mounted facing each other on the first and third baffles.

5. A loudspeaker system according to any of the preceding claims, wherein means are provided in the opening between the enclosure and the first baffle as to trap unwanted resonances occasioned by the radial increase in cross section of openings with respect to the axes of the transducers failing to comply with an exponential law.

6. A loudspeaker system according to Claim 4, wherein means are provided in the opening between the first and third baffles so as to trap unwanted resonances occasioned by the radial increase in cross section of openings with respect to the axes of the transducers failing to comply with an exponential law.

7. A loudspeaker system substantially as hereinbefore described with reference to, and as illustrated in, Figures 1 to 4, Figure 8, and Figures 1 to 4 as modified by Figure 5, Figure 6 and Figure 7 of the accompanying drawings.

Printed in the United Kingdom for Her Majesty's Stationery Office by the Tweeddale Press Group, 8991685, 6/87 18996. Published at the Patent Office, 25 Southampton Buildings, London WC2A 1AY, from which copies may be obtained.